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DETECTION OF TARGETS IN THREE SIMULATED SONAR PRESENTATION MODE--ETC(U)
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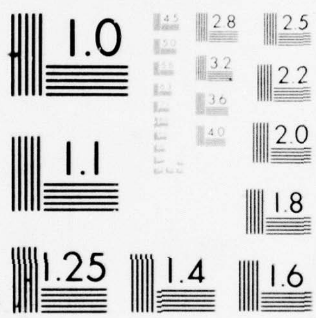

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DETECTION OF TARGETS IN THREE SIMULATED SONAR PRESENTATION MODES

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ABSTRACT

Target detection performance was compared across three simulated sonar presentation modes: single channel binaural, four channel binaural, and eight channel dichotic detection. The multichannel tasks simulated the "search" modes of the AQS-13 and AQS-13B sonars respectively. The results showed a 3.4 dB decrement in performance for the four channel task and a 4.1 dB decrement in performance for the eight channel task compared to the single channel task. Almost half the decrement in performance was due simply to the presence of the additional bands of noise, the other half to the requirement that more than one channel be monitored at a time. One possible way to improve target acquisition would be to present the channels successively on successive pings.

INTRODUCTION

<u>Background of the problem</u> - Operational Sea King Sonar systems AQS-13 and AQS-13B provide the operator with information from eight sectors of the ocean. The return from each sector is treated separately and presented as a single channel of information. These channels must then be combined in some way for presentation to the observer. If the returns from the different ocean sectors were combined and presented together at a single display frequency the reverberations would combine to decrease the detectability of a target in any one sector. Combining two channels would reduce the detectability of a target on either by 3 dB. Combining eight channels would produce a theoretical decrement of 9 dB. Accordingly, in operational systems, the channels are separated. Returns from the different ocean sectors are presented at different display frequencies, and in some cases separately to the two ears. The usefulness of this mode of presentation depends on the operator's ability to monitor simultaneously several separate channels.

<u>Prior studies</u> - The human's ability to monitor several sources of information simultaneously has been extensively examined. Relevant studies have been carried out by Morton and Copeman (1968), and by Klumpp and Leonard (1972). Both studies measured the detectability of an auditory signal which might occur on any of several channels on a given trial. Morton and Copeman (1968) measured detectability of a signal in four different tasks - single channel binaural, two channel binaural, two channel dichotic; and four channel dichotic. Comparing the single channel binaural with the remaining three conditions, they found decrements of 1.29, 2.27 and 2.99 dB respectively. Klumpp and Leonard (1972) found decrements of only .9 and 1.1 dB on comparing performance in a single channel task with that on a four channel binaural and eight channel dichotic task. Both studies have a number of limitations. Morton and Copeman (1968) did not simulate the four channel binaural and eight channel dichotic tasks used in current sonar systems. Klumpp and Leonard (1972) only measured single channel performance at 1000 hz. Thus their results only hold true for the one frequency. Furthermore, their masker consisted of a pair of two-second samples of reverberation, with the same two samples being used on every trial. This differs from the constantly fluctuating reverberation pattern in an operational situation.

<u>Current study</u> - The current study compared performance on a single channel binaural, a four channel binaural and an eight channel dichotic task. The two multi-channel tasks simulated the search modes of the AQS-13 and AQS-13B systems. In AQS-13 search mode,

returns from four sectors are presented binaurally at four display frequencies. The remaining four sectors are presented on the next ping. In the AQS-13B returns from four sectors are presented to one ear at four separate frequencies with the remaining sectors being presented simultaneously and independently to the contralateral ear at the same set of frequencies. Target detection performance was measured with the observers listening for targets on each channel separately, both with a single band of noise as masker and with the same maskers as in the multichannel tasks. These control conditions were compared with performance measures in the two multi-channel tasks, when the target might appear on any channel in any one trial.

METHOD

Experimental conditions - Detectability of a signal was measured under five experimental conditions. They differed in the number of channels an observer had to monitor and in the masker in which the signal was imbedded. Figure 3 summarizes the five conditions in terms of number of different signals presented and number of noise bands used. A channel was defined as a narrow band of noise (50 hz wide) within which a sinusoidal signal might be presented at the centre frequency of the noise. In all conditions the observer's task was to indicate in which of two otherwise equivalent time intervals a signal had occurred.

S1-N1 (one signal, one noise); single frequency binaural signal detection in a single band of noise. This condition corresponded to the tracking mode of the AQS-13. The masker was a single band of noise centred on the frequency of the signal. The signal was a sinusoid of known frequency. Performance was measured at 640, 1000, 1390 and 1740 hz. Both signal and masker were presented binaurally (same presentation to each ear).

S1-N1 (one signal, one noise, monaural); single frequency monaural signal detection. For three observers performance was measured when the signal and masker were presented to only one ear at a time.

S1-N4 (one signal, four noises); binaural single channel signal detection in four bands of noise. The signal was the same as in S1-N1. The masker was composed of four bands of noise each 50 hz wide centred at 640, 1000, 1390 and 1740 hz. Both signal and masker were presented binaurally. Performance was measured with the signal at each of the four masker centre frequencies.

S4-N4 (four signals, four noises); Binaural four channel signal detection. The masker was identical to S1-N4. The signal frequency was randomly selected at the start of each trial to be at the centre frequency of one of the noise bands. This resulted in approximately 20 trials at each signal frequency within a run. S4-N4 corresponded to the search mode of the AQS-13.

S1-N8 (one signal, eight noises); Monaural single channel signal detection in eight bands of noise. The signal here was the same as in S1-N1 and S1-N4 except it was presented monaurally. The masker was composed of eight bands of noise. Four bands, each centred at a different frequency, were presented to one ear; the remaining four, at the same centre frequencies but independently generated, were presented to the other ear. The frequencies used were the same as for S1-N4. Performance was measured with the signal at each display frequency and in each ear.

S8-N8 (eight signals, eight noises); Eight channel dichotic signal detection. The masker was the same as in S1-N8. The signal frequency and ear were randomly selected at the beginning of each trial. Approximately 10 signals were presented on each channel during a run. This condition simulated the AQS-13B search mode.

Observers - 5 (4 female, 1 male) observers, all with normal hearing, were used in this study. Each observer was run in every condition.

Apparatus and stimuli - A simplified schematic of the system used to present the stimuli to the observer is shown in Figure 1. The sinusoid being generated was first low pass filtered at 2000 hz to remove unwanted harmonics. Next the gating of the sinusoid and signal interval selection was carried out. A second low pass filter removed transients generated by this process. The signal was then fed into one of two mixers via a switch (ear selection switch) under computer control. Here it was mixed with one of the prerecorded tracks of narrow band noise and a wide band noise source. The combined stimuli were fed to one earphone while the other earphone received the output of the second track of prerecorded noise and the second wide band noise source. For the binaural condition the ear selection switch was fixed and the output of the mixer containing the signal was fed to both earphones. The levels for each signal and noise path were separately adjustable.

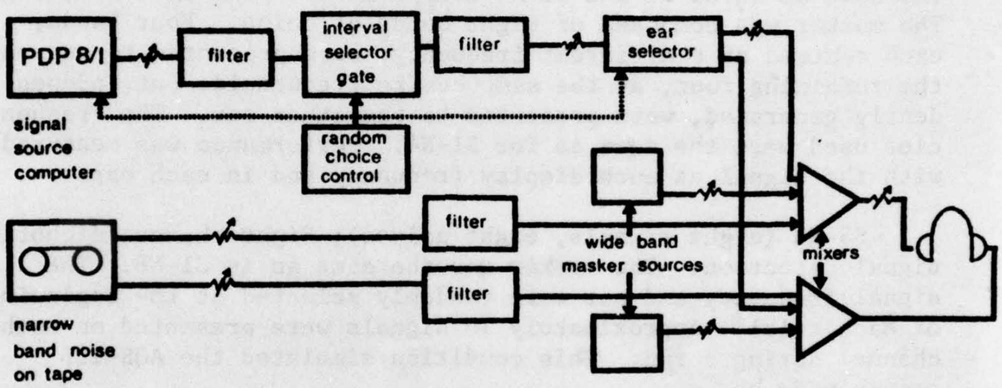

Figure 1: A schematic diagram of the stimulus flow control. The PDP 8/I generates the signal and controls ear selection. For the binaural mode the normal input to the right earphone was eliminated and the input to the left earphone fed to both. Ear selection was not carried out in the binaural mode.

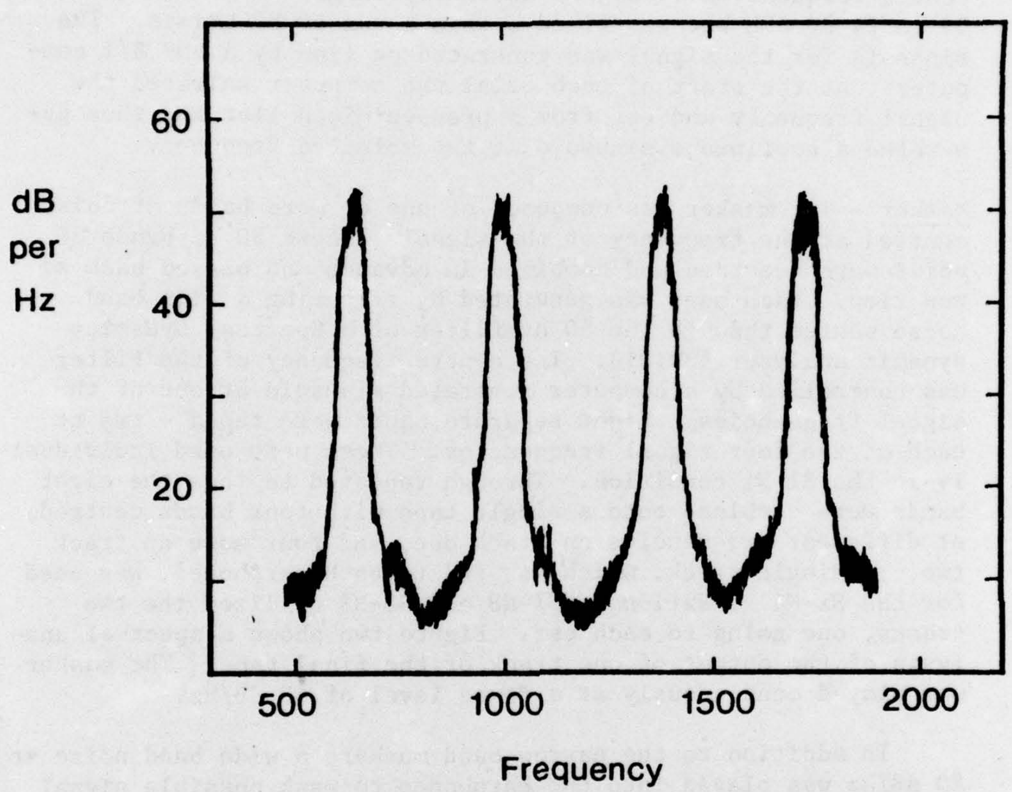

Figure 2: Spectral analysis of the narrow band noise sources from one track of the tape recording used in this study. The wide band noise was set at 20 dB per hz.

Signal - The signal was a 500 millisecond burst of a sinusoid with 100 millisecond on and off ramps. The frequencies used were 640, 1000, 1390 and 1740 hz (the same as the noise band centre frequencies). Signal intensity ranged between runs from 59 to 74 dB SPL but was fixed within a run of 80 trials. The sinusoid for the signal was generated on line by a PDP 8/I computer. At the start of each trial the computer selected the signal frequency and ear from a predetermined list and then generated a continuous sinusoid at the selected frequency.

Masker - The masker was composed of one or more bands of noise centred at the frequency of the signal. These 50 hz bands of noise were recorded and combined in advance and played back at run time. Each band was generated by filtering a wide band noise source through the 50 hz filter of a Spectral Dynamics dynamic analyser #SD101B. The centre frequency of the filter was controlled by a computer generated sinusoid at one of the signal frequencies. Eight separate bands were taped - two at each of the four signal frequencies. These were used individually in the S1-N1 condition. Through repeated tapings the eight bands were combined onto a single tape with four bands centred at different frequencies on track one, and four more on track two. A single track, which was fed to both earphones, was used for the Sx-N4 conditions. S1-N8 and S8-N8 utilized the two tracks, one going to each ear. Figure two shows a spectral analysis of the output of one track of the final tape. The masker was played continuously at a fixed level of 50 dB/hz.

In addition to the narrow band maskers a wide band noise at 20 dB/hz was played into the earphones to mask possible signal switching transients and apparatus hum.

Responses - An observer was required to indicate in which of two intervals a signal had occurred by pressing the appropriate button. Responses were recorded by the computer and stored on dectape. At the end of each run the computer printed out the percent correct on each channel monitored.

Procedure - Observers were run three hours a day five days a week. While carrying out the task an observer was seated in a soundproof booth. Each session in the booth lasted 20 minutes and was composed of three runs of eighty trials each. Two observers ran alternately throughout the three hour period. Within a run all variables were fixed except for the multi-channel conditions, for which the signal frequency and ear were randomly selected at the beginning of each trial. Between runs the signal level was shifted. Each trial consisted of a 0.2 second warning interval, two 0.6 second signal listening intervals

separated by a 0.3 second pause, and a 0.9 second response interval. The five intervals were marked by lights. Feedback was given immediately after a response was made.

DATA ANALYSIS

Raw Data - The raw data was in the form of percent correct. The initial step was to determine the average percent correct for each combination of frequency, observer, ear, experimental condition, and signal level. For S1-N1, S1-N4 and S1-N8 these averages were based on one or two runs of 80 trials each. A second run under a given set of conditions was made if the first differed appreciably from the midpoint between its neighbours. The S1-N1 and S1-N1m conditions (binaural and monaural data from S1-N1) were found to show no differences, and were averaged together. Each value for S4-N4 and S8-N8 was based on 160 to 200 trials collected over several runs. It is impossible to be more precise since the number of trials on each channel varied from run to run.

d' values - For each of the above averages the equivalent d' value was calculated. d' usually increases logarithmically with signal energy measured in dB in a detection task. A straight line was fit to each plot of log d' versus signal level in dB at each combination of conditions, using the method of least squares. The coefficients of determination of these regressions ranged from .69 to .99 with 80% being .9 or greater.

Differences amongst conditions - The signal level giving d' = 1 was calculated for each condition and observer. d' = 1 is equivalent to 76% correct. The standard error of the estimate of each signal level for a fixed value of d' was 0.7 dB on average. Next the differences between the multi-channel tasks and the single channel tasks for each frequency, ear and observer at d' = 1 were determined. These values and the signal levels they were derived from are recorded in Table A1 and A2 in Appendix A. The differences form the results of the study.

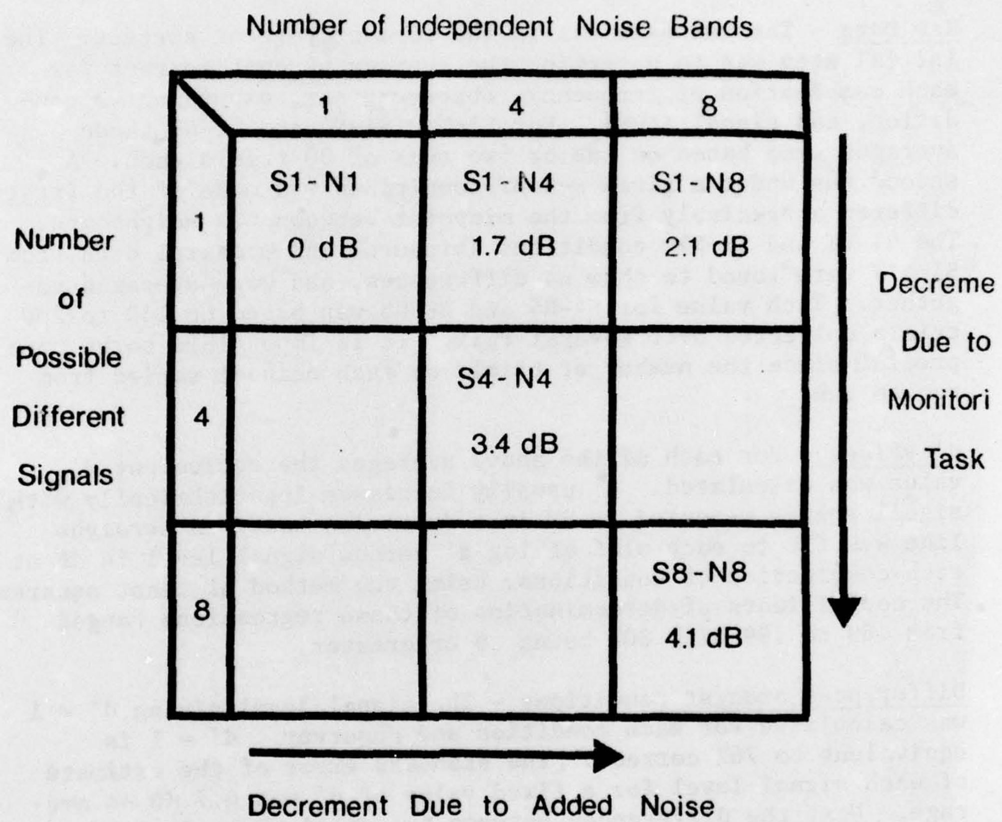

Figure 3: The five experimental conditions shown in terms of number of different signal frequencies presented during a run and the number of noise bands presented simultaneously. The decrement associated with each condition is also included.

RESULTS

Differences between multi-channel and single channel tasks - Performance in the multi-channel tasks was compared with performance in the two single channel tasks. The average differences at d' = 1 are summarized in Table I and Figure 3. Each mean and standard deviation is based on an n of 20. Figure 3 gives the average decrements relative to S1-N1 for each condition. The differences between the single channel conditions S1-N4 or S1-N8 on the one hand versus S1-N1 on the other, gives a measure of the effect of the additional bands of noise on signal detectability. The differences between the multi-channel tasks (S4-N4 and S8-N8) and their relevant controls (S1-N4 and S1-N8) gives a measure of the decrement attributable to having to monitor several channels simultaneously. In this study there was no difference between monitoring four channels binaurally and eight channels dichotically. The 0.7 dB difference between S4-N4 and S8-N8 was attributable to the difference between the noise conditions and not to the monitoring of extra channels.

TABLE I

Average Differences in Performance in dB at d' = 1 between

Related Conditions across Frequency and Observer

	(S1-N4) -(S1-N1)	(S4-N4) -(S1-N4)	(S4-N4) -(S1-N1)	(S1-N8) -(S1-N1)	(S8-N8) -(S1-N8)	(S8-N8) -(S1-N1)
MEAN	1.5	1.9	3.4	2.3	1.8	4.1
S.D	.88	.71	.83	.89	.82	.95

Performance at individual frequencies - The decrements in performance due to the presence of additional noise bands and to having to monitor more than one channel have been plotted in Figures 4 and 5 for each frequency and observer. Figure 4 shows the decrement due to the presence of additional noise bands. For (S4-N1) - (S1-N1) the effect of the additional bands of noise appears to be frequency dependent. The decrement was greater when the primary masker was bracketed by the additional noise bands. When eight bands of noise were present the effect of the additional

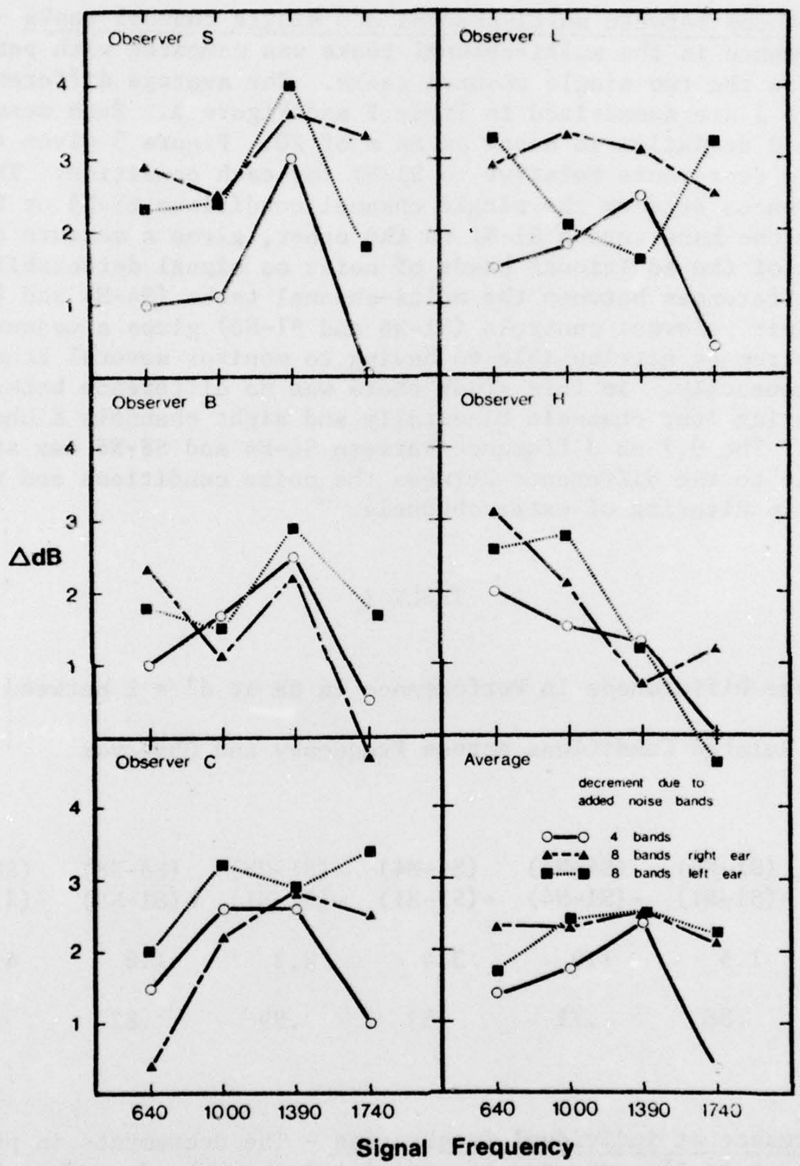

Figure 4: The decrement in performance due to the presence of added noise bands in the four channel task, and the eight channel task at each ear (S8-N8 only), frequency, for each observer, and averaged across observers. Larger y values indicate greater performance decrement.

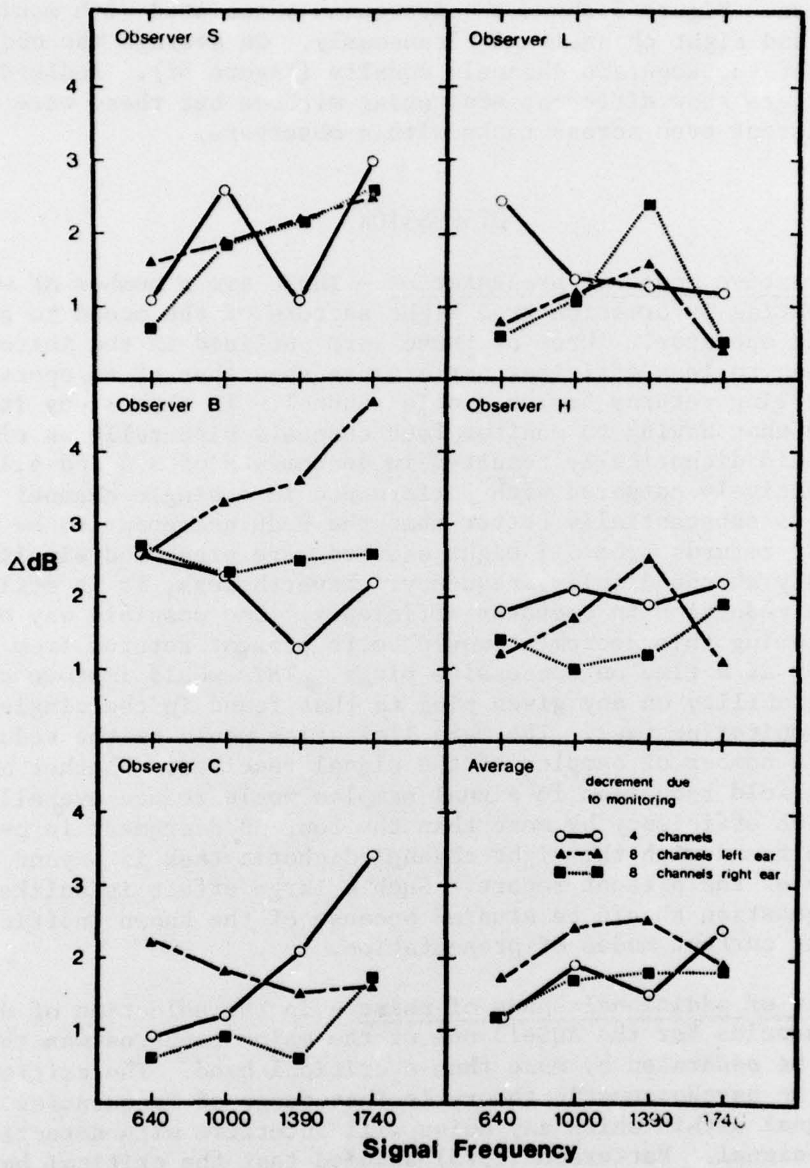

Figure 5: The decrement in performance due to monitoring several channels for each ear (S8-N8 only), frequency, observer and the average across observers. Increasing values along the y axis represent greater decrement in performance.

bands showed a similar but weaker and statistically unreliable pattern. Figure 5 shows the decrement associated with monitoring four and eight channels simultaneously. On average the observers monitor the separate channels equally (Figure 5f). Individual observers show different monitoring methods but these were not consistent even across tasks within observers.

DISCUSSION

Alternative modes of presentation - There are a number of ways of presenting information from eight sectors of the ocean to a single operator. Three of these were outlined in the introduction. All led to less efficient performance than that of an operator monitoring returns from a single channel. In this study it was found that having to monitor four channels binaurally or eight channels dichotically resulted in decrements of 3.4 and 4.1 dB respectively compared with performance in a single channel task. This is substantially better than the 9 dB decrement to be expected if returns from all eight sectors were presented simultaneously at one display frequency. Nevertheless, it is still a large reduction in operator efficiency. One possible way of overcoming this decrement would be to present returns from one sector at a time on successive pings. This would improve signal detectability on any given ping to that found in the single channel monitoring task. The main limitation would be the reduction in the number of samples of the signal received. Whether an eight fold reduction in signal samples would reduce overall detection efficiency by more than the four dB decrement in performance found with the eight channel dichotic task is beyond the scope of the present report. Such a large effect is unlikely. The question should be studied because of the known inefficiency of the current modes of presentation.

Effect of additional bands of noise - In the selection of display frequencies for the AQS-13 one of the major concerns was that they be separated by more than a critical band. The critical band in psychoacoustic theory is that range of frequencies around a signal within which any noise will interfere with detection of that signal. Patterson (1975) assumed that the critical band could be represented by a simple filter and measured its shape. Using his estimate of critical band filter shape, the total noise energy added to the primary masker of a given signal by neighbouring noise bands in the complex masker would be less than 0.1 dB in the worst case. The effect of these added noise bands on signal detectability should be no greater. Interference between the sounds presented to the two ears should also be minimal. Significant contralateral masking does not occur unless the

noise in the contralateral ear is much louder than the levels used in this study. Nevertheless the simple presence of the additional noise bands in this study resulted in performance poorer by 1.5 to 2.3 dB.

The four channel binaural task versus the eight channel dichotic task - The difference between the two multi-channel tasks in this study was small. In fact two observers showed no differences at all (Table A2). Performance in the four channel binaural task was slightly better on average. This advantage might be reduced somewhat in an operational situation because the number of signal samples received doubles when the eight channel dichotic task is employed. The difference between the two tasks was due entirely to the presence of the additional noise bands. Since this decrement is not due to the simple addition of energy to the masker it is probably due to some effect on the higher level processing of the auditory stimulus. Such effects might be increased by the stresses of a vigilance situation and the presence of intense extraneous noises and situational requirements of an operational environment.

CONCLUSION

A multi-channel task impairs target detection. The intensity of a signal which is detectable 76% of the time in the tracking mode must be increased between 3.4 and 4.1 dB to be equally detectable in the multi-channel mode. Given this level of decrement it would be useful to consider an alternative mode of presentation. Presenting returns from different sectors successively would eliminate the decrement due to the additional bands of noise and to having to monitor several channels simultaneously.

If a multi-channel mode seems ultimately the most desirable there is little to choose between the two modes simulated in this study. The four channel binaural mode resulted in slightly better performance. This advantage might be eliminated by reducing the effect of the complex masker. In general it would be useful to study the effect of the complex masker in further detail.

RECOMMENDATIONS

1. Returns from the eight sectors should be presented successively rather than simultaneously.

2. If a multi-channel mode of presentation is necessary because of rapid variation in target location either mode (4 sectors alternating between pings or 8 sectors presented dichotically) could be used with close to equivalent results. They should only be used for target acquisition.

3. Further study is required on ways of overcoming the effects of the complex masker which detracts from performance in the multi-channel modes.

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APPENDIX A

TABLE A1

Signal Level in dB SPL Resulting in Performance

of d' = 1 for each Combination of Frequency

Observer Condition and Ear.

OBSERVER	SIGNAL FREQUENCY	CONDITIONS						
		S1-N1	S1-N4	S4-N4	S1-N8		S8-N8	
					RIGHT	LEFT	RIGHT	LEFT
S	640	63.9	64.9	66.0	66.8	66.2	68.4	66.9
	1000	64.5	65.6	68.2	67.0	66.9	68.9	68.8
	1390	64.0	67.0	68.1	67.6	67.9	69.8	70.1
	1740	63.5	63.5	66.5	66.8	65.3	69.3	67.9
	AVERAGE	64.0	65.3	67.2	67.1	66.6	69.1	68.4
L	640	63.7	65.2	67.8	66.6	67.0	67.4	67.6
	1000	63.5	65.3	66.7	66.8	65.6	68.0	66.7
	1390	63.7	66.2	67.5	66.8	65.3	68.4	67.7
	1740	64.0	64.4	65.6	66.5	67.2	66.9	67.7
	AVERAGE	63.8	65.3	66.9	66.7	66.3	67.7	67.4
B	640	62.2	63.2	65.8	64.5	64.0	67.1	66.7
	1000	63.2	64.9	67.2	64.3	64.7	67.6	67.0
	1390	62.1	64.6	65.9	64.3	65.0	67.9	67.5
	1740	63.0	63.5	65.7	62.7	64.7	67.4	67.3
	AVERAGE	62.6	64.1	66.2	64.0	64.6	67.5	67.1
H	640	65.3	67.3	69.1	68.4	67.9	69.6	69.3
	1000	65.1	66.6	68.7	67.2	67.9	68.9	68.8
	1390	66.0	67.3	69.2	66.7	67.2	69.2	68.4
	1740	65.3	65.3	67.5	66.5	64.9	67.6	66.8
	AVERAGE	65.4	66.6	68.6	67.2	67.0	68.8	68.4
C	640	65.2	66.7	67.6	65.6	67.2	67.8	67.8
	1000	65.6	68.2	69.4	67.9	68.8	69.7	69.7
	1390	65.7	68.3	70.4	68.5	68.6	70.0	69.2
	1740	63.7	64.7	68.1	66.2	67.1	67.8	68.8
	AVERAGE	65.1	67.0	68.9	67.1	67.9	68.8	68.9

APPENDIX A

TABLE A2

Differences in Performance in dB at d' = 1 between Related Conditions for each Combination of Frequency and Observer.

OBSERVER	SIGNAL FREQUENCY	CONDITIONS					
		(S1-N4) -(S1-N1)	(S4-N4) -(S1-N4)	(S4-N4) -(S1-N1)	(S1-N8) -(S1-N1)	(S8-N8) -(S1-N8)	(S8-N8) -(S1-N1)
S	640	1.0	1.1	2.1	2.6	1.15	3.75
	1000	1.1	2.6	3.7	2.45	1.9	4.35
	1390	3.0	1.1	4.1	3.75	2.2	5.95
	1740	0.0	3.0	3.0	2.55	2.55	5.1
	AVERAGE	1.28	1.95	3.23	2.84	1.95	4.79
L	640	1.5	2.6	4.1	3.1	.7	3.8
	1000	1.8	1.4	3.2	2.7	1.15	3.85
	1390	2.5	1.3	3.8	2.35	2.0	4.35
	1740	.4	1.2	1.6	2.85	.45	3.3
	AVERAGE	1.55	1.63	3.18	2.75	1.08	3.83
B	640	1.0	2.6	3.6	2.05	2.65	4.7
	1000	1.7	2.3	4.0	1.3	2.8	4.1
	1390	2.5	1.3	3.8	2.55	3.05	5.6
	1740	.5	2.2	2.7	0.7	3.65	4.35
	AVERAGE	1.43	2.1	3.53	1.65	3.04	4.69
H	640	2.0	1.8	3.8	2.85	1.3	4.15
	1000	1.5	2.1	3.6	2.45	1.35	3.8
	1390	1.3	1.9	3.2	.95	1.85	2.8
	1740	0.0	2.2	2.2	.4	1.5	1.9
	AVERAGE	1.2	2.0	3.2	1.66	1.5	3.16
C	640	1.5	.9	2.4	1.2	1.4	2.6
	1000	2.6	1.2	3.8	2.75	1.35	4.1
	1390	2.6	2.1	4.7	2.85	1.05	3.9
	1740	1.0	3.4	4.4	2.95	1.65	4.6
	AVERAGE	1.93	1.9	3.83	2.44	1.36	3.8

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13. ABSTRACT

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4